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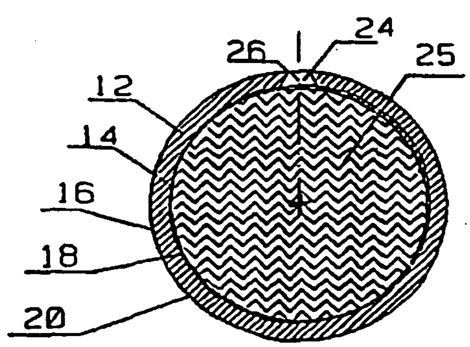

(57) Abstract

A tube (12) for irrigation is made of elastic material and is pierced with a needle (22) to form a plurality of normally closed holes (24). A fluid is supplied by the tube at a low rate of flow. In response to the pressure of the fluid within such tube, the holes open (26), controllably releasing the fluid. An increase in the pressure of the fluid within the tube results in an increase in the hole size (28).

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ELASTIC DRIP TUBES FOR IRRIGATION

Background—Field of Invention

This invention relates to elastic tubes, especially for use as drip tubes, spraying tubes, and filtering elements for irrigation.

Background—Description of Prior Art

Perforated plastic tubes have been used in drip irrigation for the past 30 years. Such tubes are perforated along their length to allow water to drip out, thus irrigating agricultural rows along which such tubes are laid. Different methods of perforating these tubes, including drilling, punching, etc., are described in "Trickle Irrigation Literature Survey", Israel Center Of Water Works Appliances, Publication PR—80767, October 1967. Additional methods of perforating plastic tubes have been developed subsequently, including the use of laser beams. Some progress has been achieved by perforating plastic tubes having different configurations, namely double-conduit plastic tubes.

Drippers, consisting of plastic tubes or channels with long paths, have been developed for creating a turbulent flow in the path, thus increasing the cross- section through which the water flows out from the tube without increasing the flow through each dripper, thereby reducing the sensitivity of the drippers to plugging. Such drippers are described in the above-mentioned literature survey.

US patent 4,779,800 to Tuomi (1988) describes a watering system comprised of a flexible transparent PVC hose, perforated by slitting the tube and punching it, using a sharp pointed curved tip of a pottery knife. Tuomi uses the flexibility of the plastic tube and the shape of the slitted holes for directing the flow of water to a designated location. Since the flow through each hole is very high, it can be used only if it is connected at both ends to the source of water.

US patent 2,779,180 to Andrews (1956) relates to a sprinkling device comprised of tubes formed in different configurations from thin, perforated, plastic sheets. The different configurations of the tubes are used for stabilizing the tubes above the ground, and directing the jets of water flowing out from the tube to the desired location.

Double conduit perforated plastic drip tubes are produced by Chapin Watermatics Inc., of Watertown, New York, U.S.A. A similar perforated plastic tube, in which perforation is done by a laser beam, is produced by Hardie Irrigation of Laguna Niguel, California, U.S.A.

Netafim of Israel, and Drip-In Irrigation Company of Fresno, California, U.S.A., produce plastic drip tubes with drippers installed inside the tube during the extrusion process of the tube. Several companies, including Netafim, produce plastic tubes with drippers connected to the tube from the outside.

The disadvantages of these systems are: (a) The flow through each dripper or hole is much higher than the required flow. As a result, large tubing is required. In an irrigation system with such devices, larger main lines, fittings, pumps, etc., are required. Many valves are required for controlling the irrigation system. Due to the high flow of water through each dripper or hole, a big portion of the irrigation water is lost by deep percolation below the root's zone of the plants. (b) Small holes and low-flow drippers are sensitive to plugging. (c) The holes and the drippers are normally open. When installing such drip tubes underground, roots and other objects may enter the holes, thus plugging them.

Objects and Advantages

Accordingly, several objects and advantages of the present invention are:(a) to provide a drip tube in which the flow through each hole is very low, as required for meeting crop requirements for water, (b) to provide a drip tube in which the holes can be prevented from plugging, (c) to provide a drip tube in which the holes cannot be plugged by objects penetrating them from outside, (d) to provide a drip tube which does not drain at the end of each irrigation cycle, and (e) to provide a tube which can spray water, with low-flow jets, for wetting a large designated area. Other objects are: (f) to provide a drip tube with a built-in filter, (g) to provide a tube which, at certain operating pressures, performs as a drip tube and, by increasing the pressure, serves as a spraying tube, (h) to provide a misting tube, operating at a low flow, with small holes that can be periodically flushed by increasing the size of the holes, (i) to provide a drip or spraying tube which can be elongated for irrigating a long strip of ground, (j) to provide a sprayer which can be used for applying a low flow of water over a large designated area, and (k) to provide a filtering element with small holes that can be periodically enlarged and flushed.

Further objects and advantages are to provide a simple solution for producing perforated tubes with accurate small holes in a simple method which will become apparent from the enclosed description and drawings.

Yet further objects and advantages will become apparent from the drawings and ensuing description.

Drawing Figures

Figs 1a through 1f show various aspects of a round, pierced, elastic drip tube according to the invention.

Figs 2a through 2f show various aspects of a pierced, elastic tube in accordance with the invention, in which the geometric shape of the tube is used for controlling the pattern of the fluid when it flows out of the tube, the flow rate of the fluid, and type of flow.

Figs 3a through 3d show a double-wall, pierced, elastic drip tube in accordance with the invention, with and without drippers.

Fig 4 shows a pierced, elastic, multiple-wall drip tube in accordance with the invention, in which one wall serves as a filter.

Figs 5a and 5b show a pierced, elastic, multiple-wall drip tube with a long capillary tube.

Fig 6 shows a liquid sprayer in accordance with the invention, comprising a pierced, elastic membrane.

Figs 7a through 7c show pressurized fluid filters in accordance with the invention, comprising pierced, elastic tubes.

Reference Numbers in Drawings

12 elastic tube	14 inside tube diameter
16 outside tube diameter	18 inside tube circumference
20 outside tube circumference	22 needle
24 pierced hole	25 fluid
26 hole at low pressure	28 hole size at pressure
30 one end of the tube	32 fluid inlet fitting
34 second end of the tube	36 plugging fitting
38 original tubes length	40 elongated tubes length
42 elastic tube	44 round portion of tube 42
46 deflector portion	48 piercing direction
50 pierced holes in deflector	52 pierced hole in tube
54 space	56 outlet from space 54
57 liquid	58 elastic tube
60 round portion of tube	62 flat portion of tube 58
64 pierced holes	66 angle of piercing

70 jets of liquid 57	72 surface of ground
74 ground	76 distance of jets
78 wetted strip of ground	80 elastic tube
82 thicker wall of tube	84 direction of piercing
86 pierced long path hole	88 elastic tube
90 flat portion of tube	92 caved portion of tube
94 direction of piercing	96 pierced hole
98 fan shape opening hole	100 elastic tube
102 thin section of tube	104 direction of piercing
106 pierced hole in 102	108 flat portion of tube
110 pierced holes	112 double conduit tube
114 main conduit	116 distributing conduit
118 common wall	120 pierced holes in 116
122 pierced holes in 118	124 interval of holes 120
126 interval of holes 122	128 group of holes 120
130 dripper	132 inlet of dripper
134 outlet from dripper	136 dripper
138 multiple walls tube	140 main conduit
142 transition conduit	144 distributing conduit
146 common wall	148 common wall
150 thin section of wall 148	152 piercing direction
154 pierced holes in 142	156 pierced holes
158 pierced holes in 146	160 piercing direction
162 pierced hole	164 pierced hole
166 unfiltered water	168 filtered water
170 main conduit	172 transition conduit
174 capillary conduit	176 distributing conduit
178 piecing direction	180 pierced hole
182 pierced hole	184 pierced hole
186 piercing direction	188 pierced hole
190 pierced hole	192 piercing direction

194 pierced hole
196 pierced hole
198 thick wall
200 thick wall
202 thick wall
204 length of tube
206 group of holes
208 flow
210 sprayer
212 elastic membrane
214 pierced holes
216 plugged end
218 fitting
220 outlet from fitting
222 space
224 direction of piercing
226 jets
228 inlet liquid flow
230 connecting tube
232 spike
234 fitting
236 liquid supply tube
238 ground
240 pierced elastic tube
242 one end of tube
244 fluid inlet fitting
246 other end of tube
248 plug
250 casing
252 space
254 end of space
256 one end of casing
258 end of space
260 end of casing
262 pierced holes
264 circumference
266 unfiltered filter
268 filtered fluid
270 elastic tube
272 elastic tube
274 elastic tube
276 main conduit
278 secondary conduit
280 delivering conduit
282 one end of tubes
284 fluid inlet fitting
286 other end of tubes
288 plug
290 fluid outlet fitting
292 pierced holes in 230
294 pierced holes in 202
296 pierced holes in 234
298 unfiltered fluid
300 filtered fluid
302 circumference
304 pierced surface length
306 rib 308 outlet of 244
310 outlet from conduit 240
312 outlet from 250
314 direction of piercing

Description—Figs 1 through 7

Figs 1a through 1d (cross sections), and Figs 1e and 1f (top view), show a basic drip tube according to the invention. An elastic tube 12 is pierced by means of a sharp object or needle 22, as illustrated in Fig 1a. When the needle is removed, a hole 24 will be formed in the tube, as illustrated in Fig 1b. Due to the elasticity of tube 12, hole 24 will be closed, but will open as shown in Fig 1c when the pressure of fluid 25 inside the tube increases beyond a predetermined level.

Tube 12 is connected at end 30 (Fig 1e) to pressurized fluid supply fitting 32, while its other end 34 is either tied or plugged by means of fitting 36. Fluid supply fittings, shown here schematically, can be selected from different types of known fittings, including flow controls, drippers, couplers, etc.

Elastic tube 12 can be elongated or stretched in the field from length 38 (Fig 1e) to length 40 (Fig 1f). Length 40 is one and one half times length 38.

Tube 12 can be made of different elastomers, such as E.P.D.M. or silicone rubbers or from thermoplastic elastomers, such as the elastomer sold under the trademark Kraton by Shell. Tube 12 can be pierced, at any interval along the tube, during the extrusion process or in a secondary operation.

The pressure of fluid 25 inside tube 12 creates a stress on the walls of the tube. When the tube is round, the pressure creates a tensile stress on the walls, forcing inside diameter 14 and outside diameter 16 of tube 12 to increase. Since elastomers cannot be compressed by applying a stress, the two diameters of elastic tube 12 increase. Inside circumference 18 increases (elongates) more than outside circumference 20, thus forcing pierced holes 22 along round tube 12 to open to a cone shape 26.

At any fluid pressure lower than a preset pressure Pc, pierced holes 24 remain closed, as illustrated in Fig 1b.

At any nominal pressure Pn higher than Pc, pierced holes 24 open to a certain size 26, as illustrated in Fig 1c.

At any fluid pressure Ph higher than Pn, pierced holes 24 increase their size from 26 to 28, as illustrated in Fig 1d.

The size to which pierced holes 24 open is correlated to the pressure of the fluid within the tube, the physical properties of the elastomer; the geometric shape and dimensions of the tube, the wall thickness of the tube at a piercing point, the piercing direction, etc. When the flow of fluid into the tube is controlled by a flow control, namely fitting 32, at any pressure the total flow through all holes 24 along the tube is controlled and equal to that of the flow

control. Since the tube is elastic, its original length can be increased to more than twice its original length.

For example, a 10-meter-long silicone tube 12 having an inside diameter of 4 mm and an outside diameter of 5 mm is pierced with a sewing needle at intervals of 20 cm. The tube, which has 50 pierced holes, is connected at one end to a source of water and its other end is plugged.

At a pressure of 0.5 bar the holes stay closed.

At a pressure of 0.7 bar the holes open themselves to a size of about 70 microns and water flows out through each hole at an average flow of 0.16 liter/hour/hole, or a total flow of 8 liters/hour.

At a pressure of 1.2 bar the size of the holes increases to 160 microns and the flow through each hole increases to 1 liter/hour.

By holding one end of the tube at a fixed place and by pulling its other end, the 10-meter tube can be stretched to 20 meters. By affixing the two ends of the stretched tube in position, the 10-meter tube can be used for irrigating a 20-meter long strip of ground.

By connecting an 8-liter/hour flow control to the inlet of the tube, the total flow through all 50 holes is controlled at 8 liters/hour, or an average flow of 0.16 liter/hour/hole.

By periodically increasing the pressure inside the tube for 2 minutes once a week, or by periodically stretching the tube physically, the holes will be periodically cleaned.

Figs 2a to 2f

Figs 2a through 2f show different means for controlling the liquid that flows out through the holes in the pierced elastic tubes.

Figs 2a through 2f illustrate different means of controlling:

- -the pattern of liquid that flows out from the tube through the pierced holes;
- -the flow rate at which the liquid flows out from the tube, through the holes;
- -the fluid pressure at which the holes open;
- -the type of flow: drops, jets, or mist.

Fig 2a (cross section) shows an extruded elastic tube 42, according to the invention. It comprises a round portion 44 and a deflector 46, forming an open space 54 between the round portion and the deflector. Space 54 has an outlet 56. Tube 42 is pierced in direction 48 through the deflector and the round part of the tube, creating pierced holes 50 and 52.

At a liquid pressure Pn, liquid 57 flows out from round portion 44 of tube 42, through pierced holes 52, to space 54. Since the pressure at open space 54 is low, pierced holes 50 remain

closed and the liquid continues to flow from space 54, out through outlet 56, in a direction and to a location which is controlled by deflector 46. Deflector 46 may have different geometric shapes with different angles for directing the liquid to any desired location. Deflector 46 is especially useful in preventing irrigation water from flowing out of the tube in jets, and for concentrating the water close to the tube. This type of irrigation is known as drip irrigation.

For example, the deflector can be 5 mm wide and 1 mm thick in order to prevent the liquid from flowing out of the tube in jets.

By using a high liquid pressure of 4 bars, and by forming the deflector with a proper shape, the jets break the water to fine drops, flowing out from the tube in a mist.

Fig 2b (cross section) and Fig 2c (top view) illustrate an elastic tube which is especially useful for spraying irrigation water. Tube 58 is extruded with round portion 60 and flat base 62, for installing the tube on flat surface 72 of ground 74. Holes 64 are pierced in the tube at an angle 66.

At a liquid pressure Pn, the liquid flows out from tube 58 through holes 64 in jets 70, wetting a strip 78 of ground. The size of holes 64, distance 76, and the rate of the liquid flow through each hole are correlated to the operating pressure.

As illustrated in Fig 2c, tube 58 sprays a liquid to a distance 76 for wetting a strip 78 of ground.

For example, at a water pressure of 2 bars inside an elastic tube, water flows out in jets, each at a low flow, to a distance of 4 meters from the tube, wetting a strip of ground 8 meters wide.

Fig 2d (cross section) illustrates a round, elastic tube 80 with a thicker portion 82, pierced in direction 84, and creating long-path, pierced hole 86.

At a liquid pressure Pn, liquid 57 flows through a long path. The long path of the hole is used for decreasing the flow of liquid through the hole. Since the flow of the liquid is also correlated to the wall thickness of the tube at the piercing point, piercing the tube at a thick portion decreases variations in flow through holes in the same tube.

For example, the tube can be extruded with a wall thickness of 0.5 mm. However, along a 4 mm section of its circumference, at the piercing point, the wall thickness is 10 mm. Liquid that flows out through the hole passes through a 10-mm-long path. Small variations in the wall thickness along the tube, created during the extrusion of the tube, have little effect on the flow of liquid through each hole along the tube.

Fig 2e (cross section) illustrates an elastic tube 88 with a flat portion 90 and inwardly protruding portion 92. The tube is pierced in direction 94, creating pierced hole 96.

The geometric shape of tube 88 is used for controlling the geometric shape of holes 96 when they open in response to the pressure of liquid 57. The stress created by the pressure of the liquid will force the inner caved portion at section 92 to decrease its length. At the same time, the outside portion of section 92 will increase its length, thus causing the holes to open in a fan or cone shape 98. Holes of such shape are useful, with and without deflectors, for spraying and misting irrigation water.

Fig 2f (cross section) illustrates elastic tube 100, which has a thinner wall at section 102, and a flat bottom 108. Tube 100 is pierced in direction 104, creating pierced holes 106 and 108. Holes 110 are made in the thicker portion of tube 100.

Since pressure Pc is correlated to the thickness of the tube at the piercing point:

-at any liquid pressure lower than pressure Pc1, no liquid will flow out from the tube,

-at any liquid pressure higher than pressure Pc1 and lower than pressure Pc2, liquid flows out from the tube only through pierced holes 102, hitting flat portion 108 and dripping close to the tube, while holes 110 remain closed, and

-at any liquid pressure higher than pressure Pc2, liquid also flows out from the tube through holes 110, in jets 70.

For example, by extruding a tube with a wall thickness of 1 mm at its round portion and with a 4 mm section of its circumference having a wall thickness of only 0.5 mm, the tube can be used for different applications as follows:

-at a water pressure of 0.5 bar, all the holes remain closed,

-at a water pressure of 1.2 bars, only holes pierced in the thinner section of the tube open and water flows out from the holes, hitting the flat base of the tube, and wetting the ground along the tube, and

-by increasing the water pressure to 2 bars, the holes pierced in the thicker portion of the tube also open and the water flows out in jets, wetting an 8-meter-wide strip of ground.

Figs 3a to 3d

Figs 3a through 3d show double-conduit elastic drip tubes according to another embodiment of the invention. These are especially useful for irrigating long rows.

Fig 3a (cross section) and Fig 3b (longitudinal cross section) illustrates tube 112, which is extruded with main conduit 114 and distributing conduit 116. The two conduits have a common wall 118. Elastic tube 112 has pierced holes 120 at close intervals 124 along distributing conduit 116, and pierced holes 122 in common wall 122 at wide intervals 126, as illustrated in Fig 3b.

Fig 3c (cross section) illustrates double-conduit elastic tube 112, with drippers 130 connected to the tube from outside, and installed at wide intervals 122 (Fig 3b). Dripper 130 has a fluid inlet 132, with its outlet 134 communicating with distributing conduit 116. Holes 120 are pierced in conduit 116 at close intervals 124 (for example, 10 cm apart) along the tube.

Fig 3d (cross section) illustrates the same elastic tube 112 with drippers 136 installed inside the tube during the extrusion process of the tube. Drippers 136 are connected to common wall 118 at wide intervals 122. Drippers 130 and 136, shown schematically, can be selected from several known types of drippers or flow controls.

At a pressure Pn, liquid 57 flows from main conduit 114 to distributing conduit 116 through holes 122. The flow of liquid through each hole 122 that enters conduit 116 flows out from tube 112 through group 128 of holes 120. Holes 120 are pierced at close intervals 124 (for example, 10 cm). Each group 128 of holes comprises a relatively short length of tube. This allows the pressure Pn of liquid 57 in conduit 114 to be high, while the pressure in conduit 116 can be low. Since the total flow of liquid through each group 128 of holes 120 is controlled by the size of hole 122 and the operating pressure, when one or more holes 120 are plugged, the flow through remaining open holes 120 in the same group 128 is increased accordingly. The piercing of tube 112 is done by controlling the depth at which a needle penetrates the tube. By short penetration at close intervals, the needle pierces holes 120. By deep penetration at wide intervals, the needle pierces holes 122 and simultaneously some holes 120.

Holes 120, pierced at wide intervals, are some of the holes in group 128. The flow of liquid through common wall 122 can also be controlled by drippers 130, as shown in Fig 3c, connected to the tube from outside, or by drippers 136 installed inside the tube, as shown in Fig 3d. Liquid 57 through each dripper flows out from tube 112, through a group 128 of holes 120, in the distributing tube. As a result, a flow of a single dripper is divided into low flow rates, flowing out through several holes 120, applying the liquid to several points along the tube.

Fig 4

Fig 4 (cross section) shows a multi-wall, drip elastic tube with a built-in filter.

Elastic tube 138 is extruded with main conduit 140, a transition conduit 142, and a distributing conduit 144. Main conduit 140 and transition conduit 142 have a common wall 146. Transition conduit 142 and distributing conduit 144 have a common wall 148, thinner at portion 150. Tube 138 is pierced at close intervals in direction 152, creating pierced holes 154, 156, and 158. Tube 138 is also pierced in direction 160, at wide intervals, creating holes

162 and 164. Holes 156 are pierced at the thicker portion of common wall 148, while holes 164 are pierced at the thinner portion 150 of wall 148.

Pressurized water flows from main conduit 140 through small holes 158, which filter the water that flows to transition conduit 142. From conduit 142, filtered water 168 flows through holes 164 in the thin section 150 of wall 148 to distributing conduit 144, and, then, out from tube 138, through groups of holes 154 and 162, pierced along the tube.

The water flows from main conduit 140, through filtering holes 158 and then through holes 164, which control the flow. The liquid then flows out of the tube through holes 154 and 162. This is achieved by piercing tube 138 at close intervals in direction 152, piercing holes 154, 156, and 158. By piercing tube 138, also at wide intervals, in direction 160, holes 162 and 164 are formed. Holes 164 are pierced through the thin section of wall 148. Holes 156, which are pierced through a thicker portion of wall 148, remain closed at a wide range of pressures.

The flow of liquid from conduit 142 to conduit 144 can be also controlled by means of drippers or flow controls, as was previously illustrated in Figs 3c and 3d.

Fig 5a to 5b

Figs 5a (cross section) and 5b (longitudinal) describe an elastic drip tube, extruded with a capillary conduit which is used for regulating the flow of water through each group of holes in the distributing conduit. The elastic tube is formed with main conduit 170, a transition conduit 172, a capillary conduit 174, and a distributing conduit 176. The tube is pierced at close intervals in direction 178, creating holes 180, 182, and 184.

At wide intervals the tube is pierced in direction 186, creating holes 188 and 190. At wide intervals and at other locations the tube is also pierced in direction 192, creating holes 194 and 196.

The tube has a thicker wall at sections 198, 200, and 202.

Water flows from the main conduit to the transition conduit through holes 184. The water is filtered when it passes through holes 184. Hole 182 is pierced at thick portion 198 and it remains closed. The water then flows from the transition conduit, through hole 190 into capillary conduit 174. Hole 202 is pierced at a thick section 202 and it remains closed.

The water then flows through a long section 204 of the capillary conduit from hole 190 to holes 196. Section 200 of the tube is thicker and hole 194 remains closed.

The water flows out from the capillary conduit into the distributing conduit and then out, through groups 206 of holes 180.

Each section 204 of the capillary conduit is used as a dripper for regulating the flow 208 of water to each group 206 of holes 180.

The secondary conduit shown in Figs 3, 4, and 5 can be produced with a small cross section of about 5 square mm. When the inside diameter of the main conduit is 13 mm and the tube applies a flow of 0.8 liter/hour/meter, such tubes can be used for irrigating a 200-meter-long row.

Each group of holes in the distributing conduit may include 100 holes at intervals of 10 cm. Each such group is pierced along 10 meters of the distributing conduit. The flow rate of 8 liters/hour to each group of holes in the distributing conduit can be controlled by a hole in the common wall, by a dripper, by a flow control, or by a capillary conduit. When using a capillary conduit (Fig 5), 8 liters/hour will flow in a 5 meter capillary conduit with an inside diameter of 1.5 mm, thus regulating the flow to each group.

A flow of 8 liters/hour then flows through 100 holes at an average flow of 0.08 liter/hour/hole.

Before entering the distributing conduit, the water is filtered by means of a built-in filter.

Fig 6

Fig 6 (partly in cross section) shows a sprayer for applying liquids at a low flow over a large designated area.

Sprayer 210 comprises an elastic membrane 212 with pierced holes 214 and fitting 218. Membrane 212 is plugged at one end 216, and its other end is connected to liquid supply fitting 218. Outlet 220 of fitting 218 is connected to space 222, enclosed in the elastic membrane 212. Tube 230 can be used for connecting sprayer 210 to liquid supply tube 236 through fitting 234. Spike 232 can be used for supporting sprayer 210 on ground 138. Holes 214 can be pierced in different directions, e.g., as illustrated at 224. Membrane 212 can be produced with different geometric shapes for controlling direction 224 of liquid jets 226. Fitting 218 or 234, shown schematically, can be a coupler, flow control, etc.

Jets of liquid, each at a low rate, flow through pierced holes in an elastic membrane. Elastic membrane 212 can be molded either as one part, with its end 216 plugged, or made from a section of extruded elastic tube, either tied or plugged. The flow rate of each jet 226, and the distance each jet travels, can also be regulated by controlling the pressure of the liquid in space 222.

The direction of each jet can be controlled by the geometric shape of the elastic membrane 212 and by the piercing angle. Different wetting patterns, including full circle, part circle, square, etc., can be achieved by selecting the proper geometric shapes and piercing angles.

The size of the holes can be altered by changing the pressure of the liquid. When the sprayer is connected to the outlet from a flow control, the total flow of liquid through all the holes is

controlled. The sprayer can be directly connected to a liquid supply tube 236 and held at an elevated position by means of connecting tube fitting 234, and spike 232.

For example, elastic membrane can have ten pierced holes. Water flows out from the holes in jets, wetting 20 square meters of ground with a total flow of only 8 liters/hour.

Fig 7a to 7c

Figs 7a and 7b (longitudinal cross section) and Fig 7c (cross section) show pressurized fluid filters; these filter fluids that flow through small holes in pierced elastic tubes.

Fig 7a shows tube 240, connected at one end 242 to fluid inlet fitting 244, and plugged at its other end 246 by means of plug 248. Tube 240 is surrounded by casing 250. Space 252 surrounds elastic tube 240 and is surrounded by casing 250. End 254 of space 252 is plugged by means of inlet fitting 254 which is also connected to end 256 of casing 250. End 258 of space 252 and end 260 of casing 250 also provide an outlet from the filter. Tube 240 has pierced holes 262 throughout its circumference 264.

Fluid 266 flows into the filter through inlet fitting 244 and flows out as filtered fluid 268 through outlet 260.

Fluid 266 flows through inlet fitting 244 into the elastic tube. In response to the fluid pressure inside the elastic tube, pierced holes 262 open and the fluid flows from the tube through the holes, filtered, continues to space 252, and through outlet 258 out from the filter.

Fig 7b illustrates a fluid filter comprising tubes 270, 272, and 274, which surround each other, creating main conduit 276, a secondary conduit 278, and a delivery conduit 280. The three tubes are connected atone of their ends 282 to pressurized fluid supply fitting 284, which plugs the fluid inlet to conduits 278 and 280, permitting the fluid to flow only into conduit 276. At their other ends 286, conduits 276 and 278 are plugged by means of plug 288, which plugs ends 286 of conduits 276 and 278. Conduit 280 is connected at its end 286 to fluid outlet fitting 290. The three tubes can be extruded as one part with a rib 306, as illustrated in Fig 7c.

Fig 7c shows a filter in which all tubes can be extruded or molded as one part with plug 288. When the three tubes are produced as one part, extruded or molded, they can be pierced in direction 314, from the outside circumference 282 of tube 274, by means of a sharp object that penetrates the walls of the three tubes, piercing holes 292, 294, and 296 throughout circumference 282, and at a length 304 of the tubes. Tube 274 has a thicker wall than tubes 270 and 272. The filter can also be produced by using only two elastic tubes 270 and 272, as either one elastic part or two separate parts. These can be enclosed in a rigid non-pierced casing 274.

Fluid 298, which needs to be filtered, flows through fitting 284 and outlet 308 to main conduit 276. In response to the pressure of the fluid in conduit 276, holes 292 open, and the fluid flows through the small holes, from conduit 276 to conduit 278, filtering the fluid for the first time. The fluid then continues to flow, through holes 294, from conduit 278 to conduit 280, where it is filtered a second time. The walls of tube 274 are thicker. Therefore, pierced holes 296 remain closed at a wide range of pressures. Filtered fluid 300 then continues to flow through conduit 280, outlet 310, fitting 290, and, then out from the filter, through outlet 312. When the three tubes are made of one elastic part, they can be pierced, by pushing a sharp object in direction 314 from the outside circumference 302 of the part through the three walls of the three tubes. For some applications, only two tubes can be used. The filter can be flushed:

-by increasing the pressure of the fluid, forcing the size of the holes to increase;

-by reversing the flow so that fluid will flow from outlet 290 through the holes and out from 284;

-by connecting tubes and flushing valves to conduits 276 and 278; or

-by periodically stretching the tubes physically.

Advantages of Invention

For any pierced elastic tube, the size to which the holes open can be controlled by the operating pressure of the fluid. By using nominal pressure Pn, the holes will open to a very small size. Then the fluid flows through each hole at a very low flow rate. This is used for applying a low flow of water for wetting a large designated area, by using many holes at close intervals. The water can flow out from the tube in drops, jets, or mist. When using such tubes in an irrigation system, small size tubing, pipes, fittings, pumps, etc. can be used because the total flow of water through each irrigation device can be very low. In an irrigation project, regardless of its size, since the flow through each irrigation tube is low, all the tubes in the project can be operated at the same time using only one main valve, eliminating the need for using many valves, controllers, etc. for operating the irrigation system.

By periodically increasing the pressure of the fluid from Pn to Ph, or by pulling up the tubes, the size of the holes can be increased 10 or 20 times. Thus, plugging of the holes can be eliminated.

At any fluid pressure lower than the pre-set, normally closed pressure Pc, the holes stay closed, and the tube stays full of pressurized fluid. In an irrigation system with such elastic drip tubes at the end of each irrigation cycle, the pressure in the system drops and the holes

close themselves, preventing water from draining from the system through the pierced holes, causing all the pipes in the system to stay full of water.

By using this method, small, accurate holes are created in the tube.

By holding one end of the tube at a fixed point, and pulling up its other end, the tube can be elongated by more than twice its original length. For example, a 50-meter drip tube can be elongated to a 100-meter tube for wetting 100 meters of ground.

Since the holes in the elastic tube are normally closed, such a drip tube can be installed under the ground without having the risk that roots, or other objects, will penetrate the holes and plug them.

A drip tube with a built-in filter reduces maintenance costs.

When, in spite of the periodic treatments described before, some holes remain plugged, new holes can be created immediately by using the awl to pierce the tube again.

Different irrigation problems can be solved by using the same tube for dripping, spraying, or misting.

A sprayer, as described, can be operated at a very low liquid flow for wetting a large designated area. A variety of distribution patterns can be achieved by using elastic membranes with proper geometric shapes and dimensions, and by controlling the operating pressure. By periodically increasing the operating pressure, plugging of the holes can be eliminated.

A filter, as described, can be produced from simple, inexpensive elements. Two or more filtering elements can be used in parallel, for safe filtration.

The holes in each tube can be enlarged and the filter can be easily flushed. Holes with long paths are used for increasing the volume of the filtering media.

While the above description contains many specific details, these are exemplary. Many part types, part sizes, materials, etc. can be made. Therefore the scope of the invention should be determined by the appended claims and their legal equivalents, not by the examples given.

Claims

1. A fluid distributing system comprising:

   a pressurized source of fluid,

   an elastic tube with a plurality of pierced holes, said holes being normally closed,

   a fluid inlet fitting,

   said holes being pierced along said elastic tube,

   one end of said tube being connected to said pressurized source of fluid by means of said fluid inlet fitting,

   the other end of said tube being closed,

   the sizes of said holes, the nature of said holes, and said pressure being correlated such that said pressurized fluid creates a stress on walls of said elastic tube and thereby causes a deformation of said walls, causing said pierced holes to open and said pressurized fluid to flow out from said tube through said holes when said pressure exceeds a preset pressure, and said holes remain closed at any fluid pressure lower than such preset pressure, the material of such tube also being such that its circumference will be substantially increased in response to said fluid pressure and thereby said size of said holes will be substantially increased.

2. A fluid distributing system according to claim 1 wherein said tube is made of a material such that its length can be substantially increased by stretching said tube.

3. A fluid distributing system according to claim 2 wherein said tube is made of a material such that the size of said pierced holes in said elastic tube can be substantially increased by stretching said tube.

4. A fluid distributing system according to claim 1 wherein the material of said tube is selected such that said holes will open at a predetermined pressure.

5. A fluid distributing system according to claim 1 wherein the wall thickness of such tube is selected such that said holes open at a predetermined pressure.

6. A fluid distributing system according to claim 1 wherein said fluid is a liquid.

7. A fluid distributing system according to claim 6 wherein the geometric shape of said tube is selected to cause a predetermined pattern of said liquid of flow out from said tube through said holes.

8. A fluid distributing system according to claim 7 wherein said liquid is irrigation water.

9. A fluid distributing system according to claim 7 wherein the geometric shape of said tube is selected to cause a predetermined type of flow of said liquid from said tube through said holes.

10. A fluid distributing system according to claim 8 wherein the length of path of said pierced hole in the walls of said tube is selected to cause a predetermined flow rate of said water through each hole in said tube.

11. A fluid distributing system according to claim 8 wherein the geometric shape of said tube said sizes of said pierced holes along said tube are selected so that the shape of said holes will change in response to pressure changes of said water along said tube, thereby causing said flow rate through said holes to become pressure compensated.

12. A fluid distributing system according to claim 8 wherein said elastic tube comprises a double conduit in which one conduit serves as a main conduit and another conduit serves as a distributing conduit, said two conduits being connected to each other by a common wall, said main conduit being pierced at relatively wide intervals, said distributing conduit pierced at relatively close intervals, so that said water which flows from said

main conduit through one hole in said common wall to said distributing conduit, flows out from said tube through a group of holes in said distributing conduit.

13. A fluid distributing system according to claim 12, further including a plurality of drippers installed in said respective holes so as to control the rate of flow of said water from said main conduit to said distributing conduit.

14. A fluid distributing system according to claim 13 wherein said drippers are connected to said tube from outside of said tube.

15. A fluid distributing system according to claim 13 wherein said drippers are installed inside said tube.

16. A fluid distributing system according to claim 13 wherein said drippers are capillary tubes.

17. A fluid distributing system according to claim 12 wherein said elastic tube includes an additional pierced elastic wall, whereby said water flows from said main conduit through said pierced holes in said additional wall, thereby filtering said water before it enters said distributing conduit.

18. A fluid distributing system according to claim 8 wherein said elastic tube is stabilized by means of a flat portion formed at the bottom of said tube.

19. A fluid distributing system according to claim 8 wherein said tube has two sets of pierced holes, one of said sets of holes being pierced at a thinner wall portion of said tube and a second set of holes being pierced at a thicker portion wall of said tube, such that when said water pressure is lower than a preset normally closed pressure, said two sets of holes remain closed, and at a range of pressures of said water higher than said preset normally closed pressure, one set of said holes remains open while said second set of holes remains closed, when said water pressure is higher than said range of pressures said two sets of holes remain open.

20. A fluid distributing system according to claim 8 wherein said tube is molded from a pierced elastic membrane, whereby the pattern and spraying distance of said jets are controlled by the geometric shape of said elastic membrane and the piercing angle of said holes.

21. A fluid distributing system according to claim 8, further including a flow control for controlling the flow of said water into said tube.

22. A fluid distributing system according to claim 1, further including a casing enclosing and surrounding said tube to form a space between outside circumference of said elastic tube and an inside circumference of said casing, said space being plugged at one end, and including means for filtering said fluid flowing from inside said tube through said pierced holes and then out through other end of said space, whereby said fluid is filtered by means of flowing through said hole, thereby said system is used as a fluid filter.

23. A fluid distributing system according to claim 22 wherein said elastic tube and said casing are made of one elastic part.

24. A fluid distributing system according to claim 22 wherein said filter is comprised of pierced elastic tubes which surround each other and said fluid is filtered by flowing through said holes in said elastic tubes and then out from said filter through said other end of said space.

25. A fluid distributing system according to claim 24, further including a plurality of valves, said inlet to said filter and said outlet from said filter being connected to said valves, whereby said filter is flushed by controlling and operating said valves.

26. A fluid distributing system according to claim 22 wherein said tube is made of foamed elastomeric material.

27. A method of supplying a fluid, comprising:

piercing an elastic tube to create a plurality of small closed holes in said tube so that said holes will open in response to the pressure of a fluid within said tube,

providing said tube with a geometric shape and dimensions which control the course of said fluid when said fluid flows out from said tube through said pierced holes, and

supplying said fluid at a predetermined pressure to the lumen of said tube, said pressure being sufficient to open said holes.

Fig. 1a

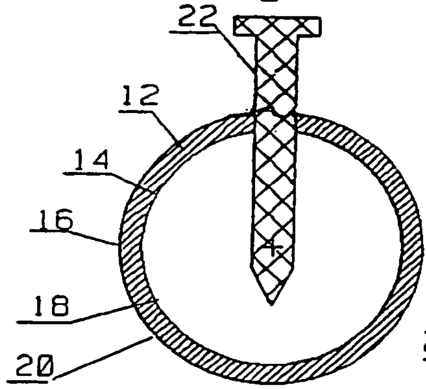

Fig. 1b

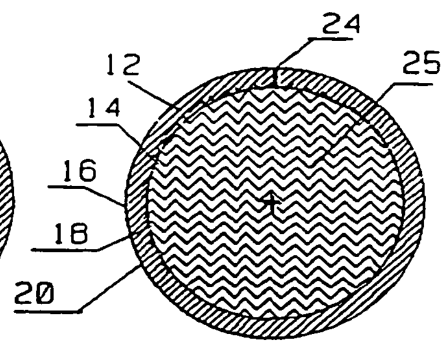

Fig. 1c

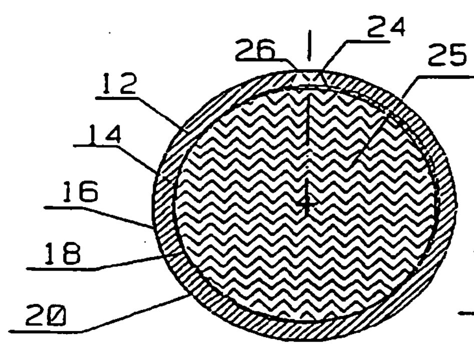

Fig. 1d

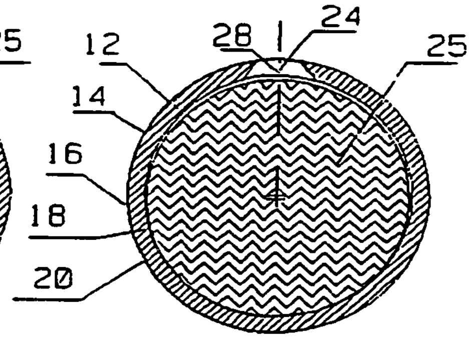

Fig. 1e

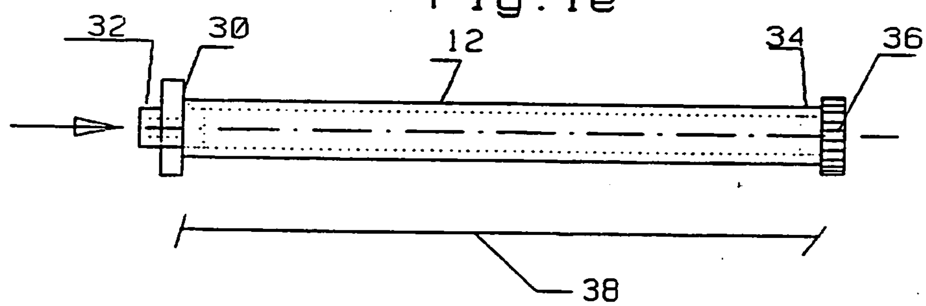

Fig. 1F

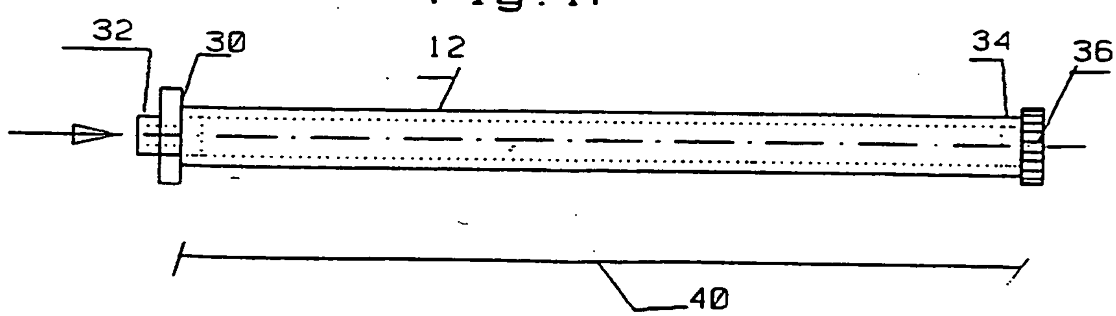

Fig.2a

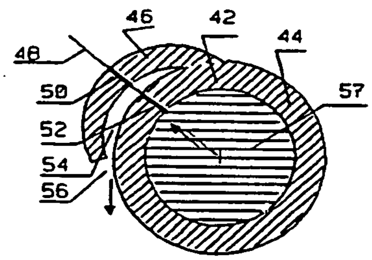

Fig.2b

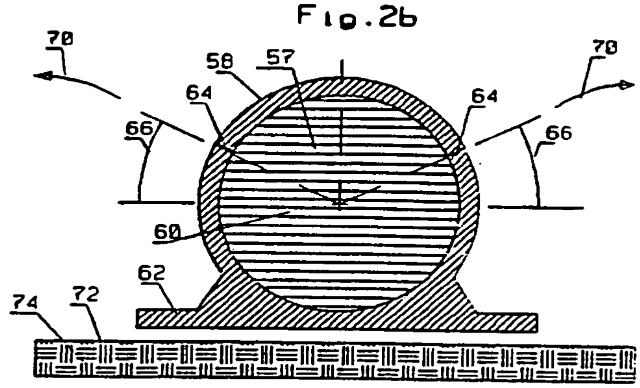

Fig.2d

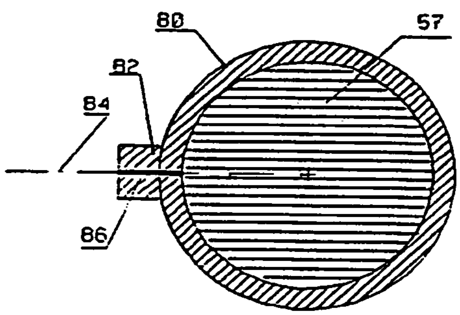

Fig.2c

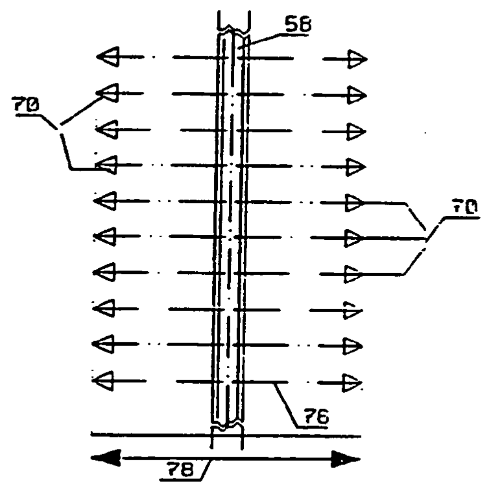

Fig.2e

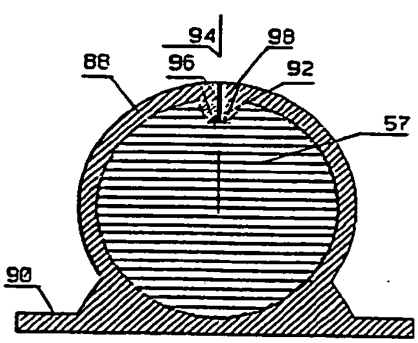

Fig.2F

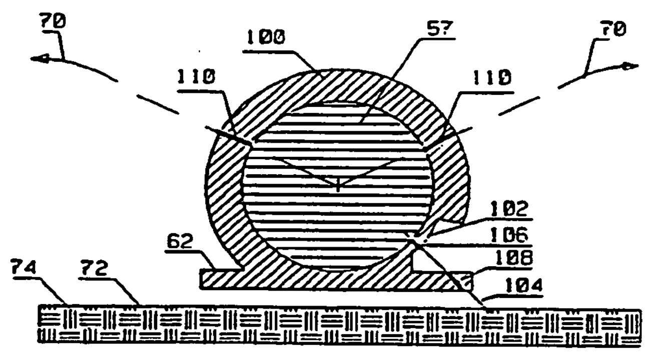

Fig.3a

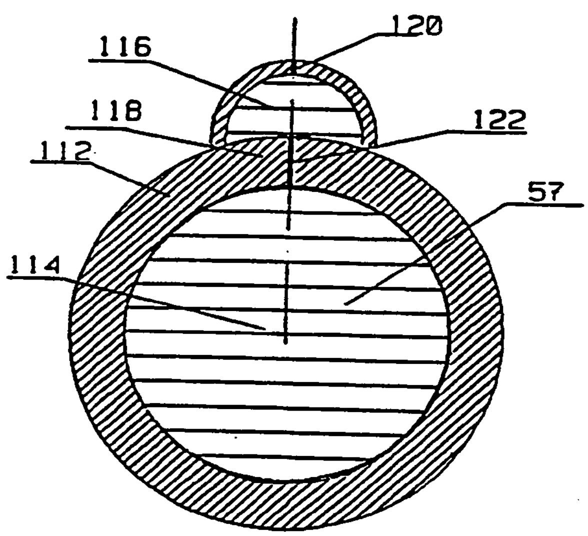

Fig.3c

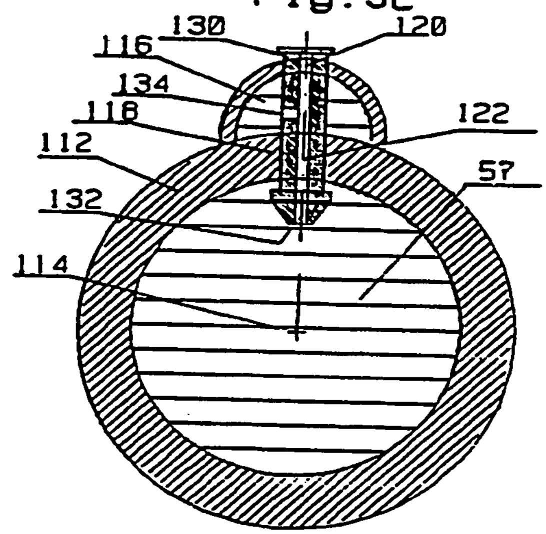

Fig.3b

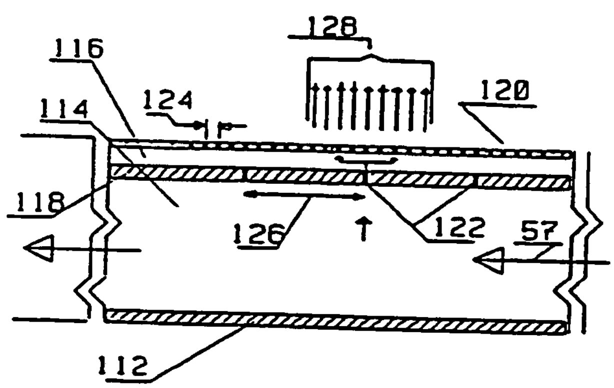

Fig.3d

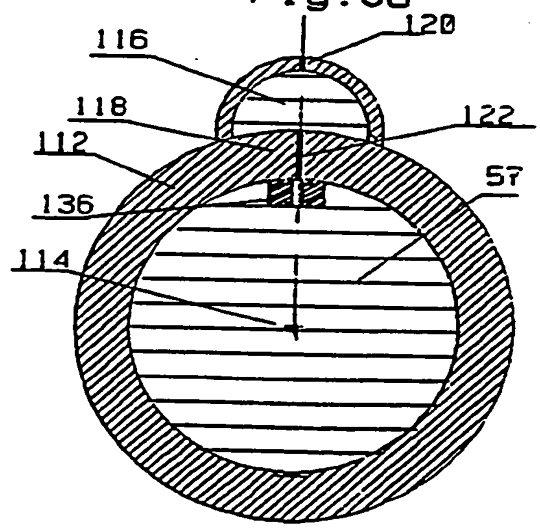

Fig. 4

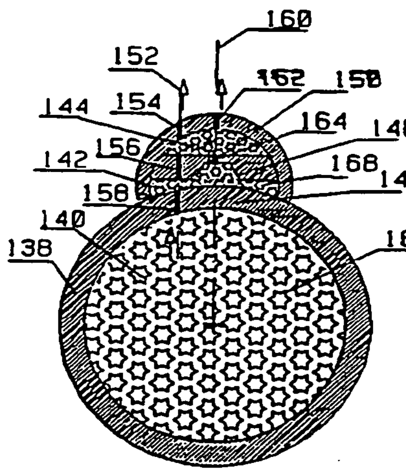
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Fig. 5

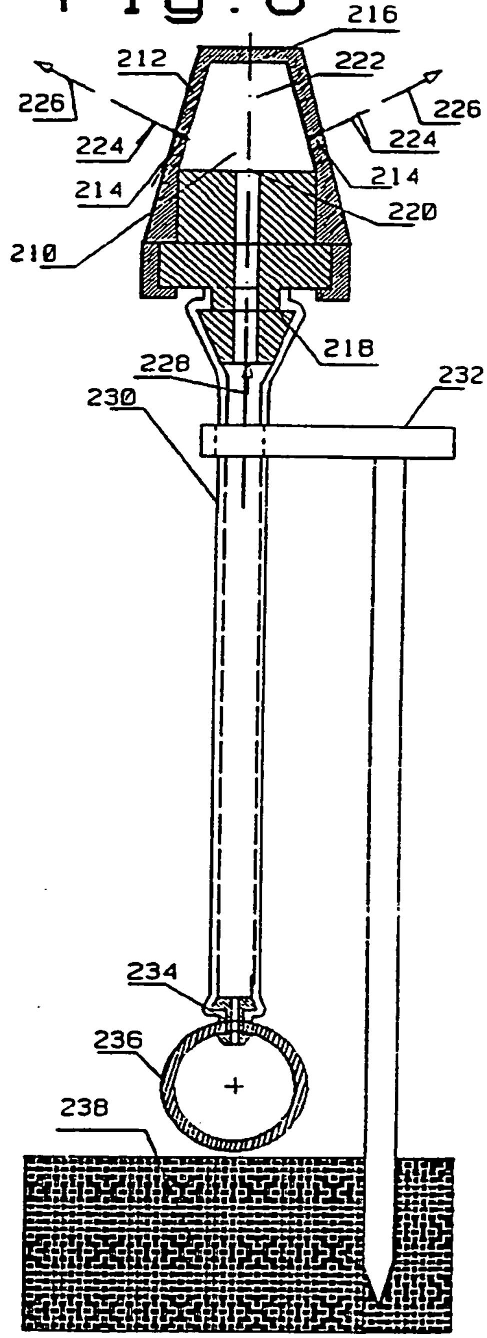
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Fig.5a

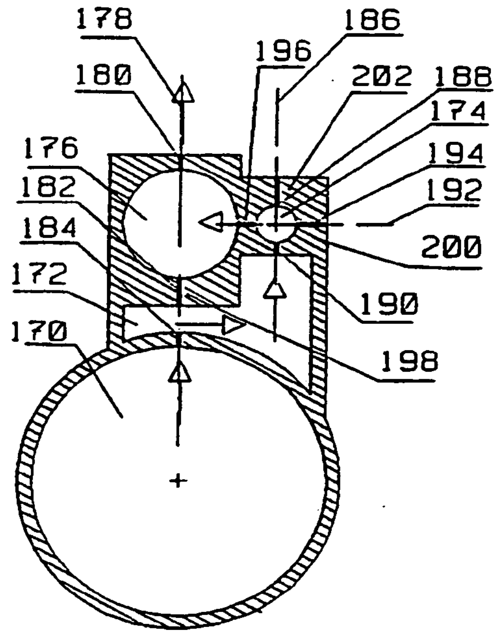
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Fig.5b

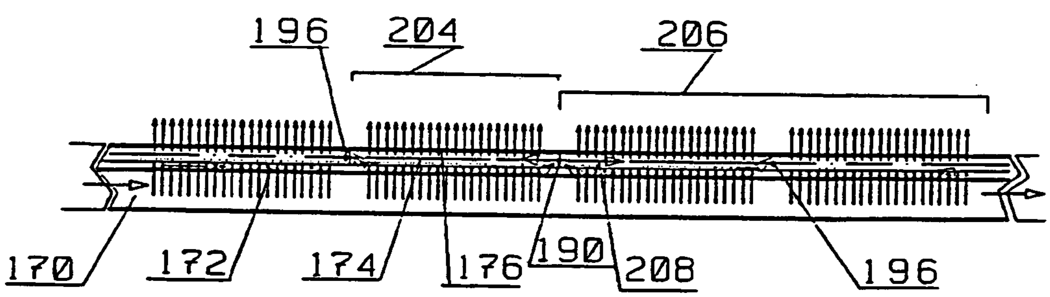
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Fig.7a

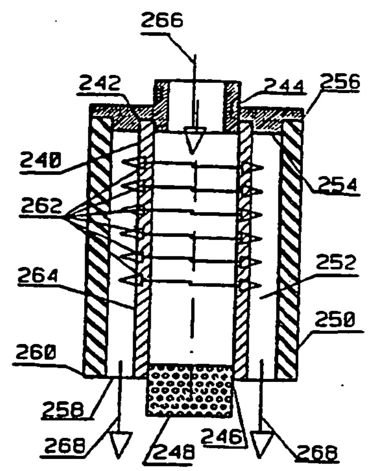


Fig.7b

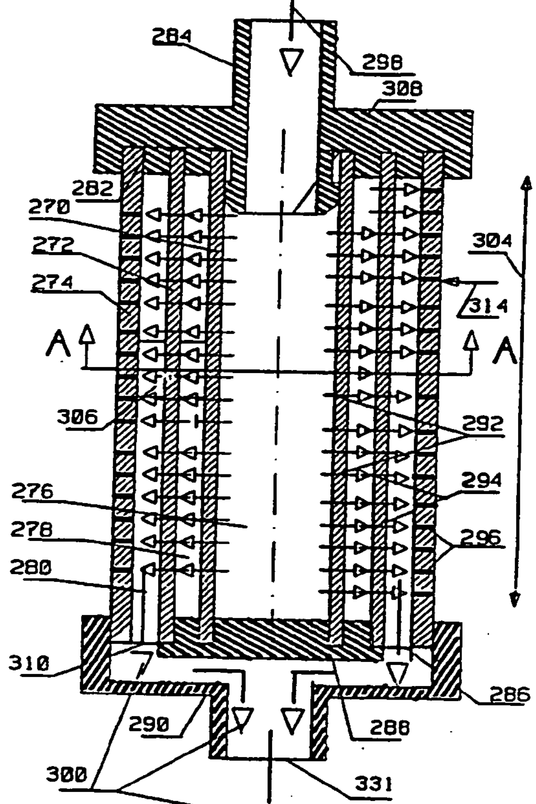
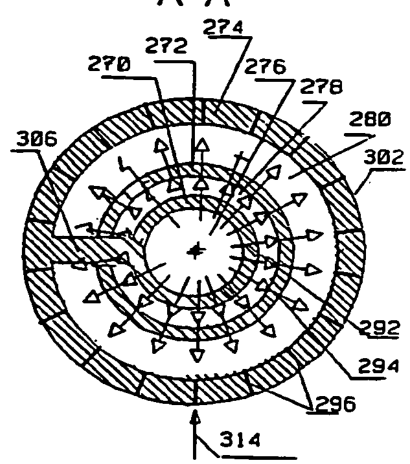


Fig.7c
A-A



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/04666

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B05B 1/30, 15/02
US CL :239/11, 107, 533.13, 542, 553.3, 602, DIG. 12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 239/11, 107, 533.1, 533.13, 542, 547, 553.3, 553.5, 562, 566, 567, 575, 602, DIG. 12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US, A, 2,771,320 (Korwin) 20 November 1956, Figs. 1, 4, 5.	1-11, 18, 20-21, 27 ---------- 12-17, 19, 22-26
Y	US, A, 4,626,130 (Chapin) 02 December 1986, Fig. 6, col. 7, lines 40-53.	12, 17
Y	US, A, Re. 28,095 (Chapin) 30 July 1974, consider the entire document.	22-26
Y	US, A, 3,860,179 (Costa) 14 January 1975, Fig. 10.	13-16

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 AUGUST 1994	AUG 05 1994

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	WILLIAM GRANT
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/04666

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

I. Claims 1-21 and 27 directed to a drip irrigation hose (Figs. 1-6).
II. Claims 1 and 22-26 directed to a fluid filter (Figs. 7a-7c).

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.